Influence of growth interruptions and gas ambient on optical and structural properties of InGaN/GaN multilayer structures

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Major developments in wide band gap III-N semiconductors have led to commercial production of high brightness light-emitting diodes and to demonstration of room temperature laser light emission under pulsed and continuos wave operation in violet [1], and, recently, in blue spectral region [2].
Single and multi quantum wells of InGaN/GaN structures are typically used as active region in these devices. There are some factors there that remarkable influence In incorporation in InGaN layers. Among them are growth temperature, cell pressure, carrier gas. Here we studied influence of growth interruption together with admixing of small amount of hydrogen in argon carrier gas on optical and structural properties of InGaN/GaN multilayer structures.
The samples studied in this work were grown by low pressure metalorganic chemical vapor deposition (MOCVD) employing an AlGaN nucleation layer deposited at 570°C on (0001) sapphire substrates. Ammonia, trimethylindium (TMI), trimethylgallium (TMG) and thrimethylaluminum (TMA) were applied as component precursors. Purified hydrogen and/or argon [3] were used as carrier gases. Active region consisting of 5×(3nm InGaN / 7nm GaN) was sandwiched between 2.5 μm-thick GaN buffer layer and 100 nm thick AlGaN cap layer.
The photoluminescence (PL) study was performed in the temperature range 4-300K using a continuous wave He-Cd laser or a pulsed nitrogen laser for excitation. Structural properties were studied using scanning electron microscopy (SEM) and transmission electron microscopy (TEM).
To investigate influence of growth interruptions (GI) set of five structures was grown:

#826 was grown under standard growth conditions (no GI, carrier gas argon)

#827 was grown with *addition of 50 sccm of hydrogen* in argon during InGaN growth (total gas flow 10 slm)

#828 was grown using argon carrier gas but with *10 sec. GI* after each InGaN QW. During the GI 50 sccm of hydrogen was added to total gas flow.

#829 was grown as #828 but with *20 sec GI* (Fig.1)

#830 was grown as #829 but *no hydrogen* was supplied during GI

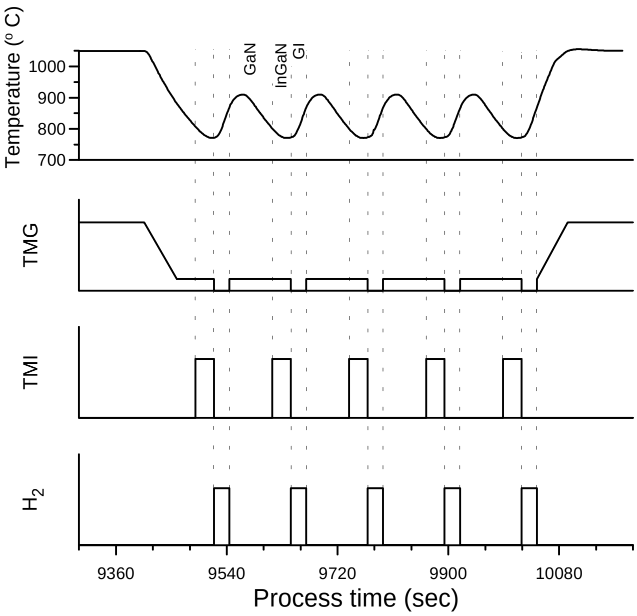

Fig.1 Sketch of growth sequence for active region of sample #829

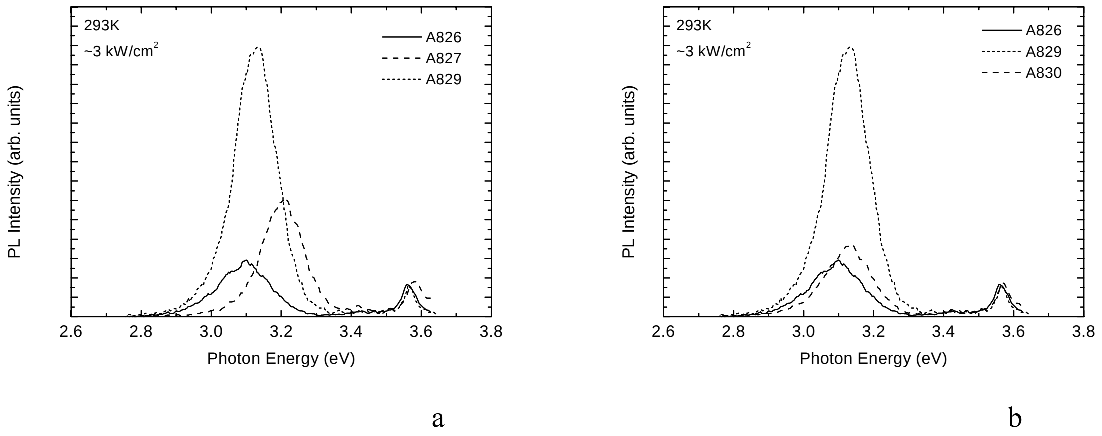

Fig.2 PL spectra for samples grown at different regimes.

Fig.2 shows room temperature PL spectra at moderate excitation densities for different samples. It is clearly seen that addition of hydrogen during InGaN growth slightly improve optical properties and strongly decrease In incorporation resulting in more than 100 meV blue shift of PL line. Long (20 sec.) growth interruption in hydrogen containing ambient strongly improves optical quality and shifts PL line to higher energies only for 40 meV. To separate influences of thermal annealing and hydrogen ambient during GI we grew structure in which no hydrogen was supplied during GI. For this structure we also observe blue shift of PL line but practically no increase in PL efficiency.

Table 1 summarizes PL data for all samples.

	Growth conditions	PL peak (eV)	PL FWHM (meV)	PL Intensity
#826	Standard	3.10	154	14600
#827	H_2 added during InGaN growth	3.21	136	31000
#828	10 sec annealing with H2	3.14	185	27000
#829	20 sec annealing with H2	3.13	134	72000
#830	20 sec annealing without H2	3.14	153	19000

So, we attribute blue shift in structures with GI only to thermal annealing and increase in PL efficiency we attribute to addition of hydrogen. On the other hand, addition of hydrogen *during* InGaN growth leads to strong blue shift of PL line that is in a good agreement with previously published results.
SEM investigations of this structures shows that samples #829 and #828 have smooth AlGaN cap layer surface, while samples #826 and #830 are characterized by some roughness of the cap layer.
Using specific growth regimes (GI with addition of hydrogen) instead of conventional growth allows us to increase EL efficiency of GaN/InGaN/AlGaN LEDs in five times.
In conclusion, we investigated influence of growth interruptions and gas ambient on optical and structural properties of InGaN/GaN multilayer structures. It is shown that optical properties of InGaN/GaN structures can be strongly improved by proper choosing of GI time and gas ambient.

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